Weatherwise

The Temperature at Your Feet

Hunting Hurricanes with the Seismograph

Boxing the Hurricane

When Summer Ends

The Northeast Dry Spell of June, 1949

Vol. 2 No. 4 August, 1949

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE" — BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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Mammato-Cumulus Clouds

MAMMATUS CLOUDS are observed from time to time during the warmer months of the year, but rarely are photographs obtained that show this phenomenon as well as our front cover and the picture in the adjoining column. These photographs were taken on August 17, 1948, by Ernest Robson, of Toulon, Illinois, in Stark County. Mr. Robson is the local observer of the United States Weather Bureau and also a member of the Photographers Association of America. In describing the conditions that day, he writes:

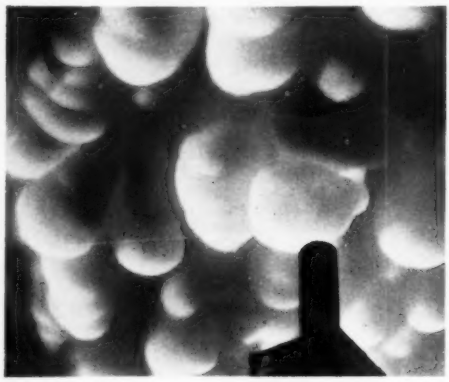
"These clouds evidently were seen in an area approximately 30 to 50 miles in diameter. Here in Toulon the clouds moved slowly, their appearance having been preceded by rather high winds, and later there was precipitation of one quarter of an inch. The clouds appeared around 6 p.m., and were seen for from one half to three quarters of an hour.

"The main disturbance at that time seems to have been to the west and southwest. A 'double' tornado was reported at Alexis, about 50 miles due west of Toulon. Other stations reported high winds, hail, and precipitation amounts of one inch at Galesburg, 1.05 inches at Moline (in an hour). Stations due south of the area where the mammatus clouds were seen reported only slight rain; and to the east there were small amounts or only traces.

"According to state climatological data, hailstones as large as baseballs fell in Whiteside County, which is to the northwest of the area where the clouds were seen, and north and east of the tornado disturbance. Tornado damage at Alexis, where two twisters were observed to merge, was estimated at 1½ million dollars."

Some doubt exists as to the exact physical process in the formation of mammatus clouds. It is a kind of upside-down convection — turn the front cover top to bottom and this effect is readily recognized.

In the **Monthly Weather Review**, June, 1919, pages 398-400, Dr. Charles F. Brooks, of Blue Hill Meteorological Observatory, discusses types of mammato-cumulus clouds; his article is preceded by several photographs of various formations. Another reference is "Convective Circulations in the Atmosphere," by D. Brunt, **Meteorological Magazine**, February, 1925, London.



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Cover: A striking example of mammato-cumulus clouds, photographed by Ernest Robson, of Toulon, Illinois, on August 17, 1948.

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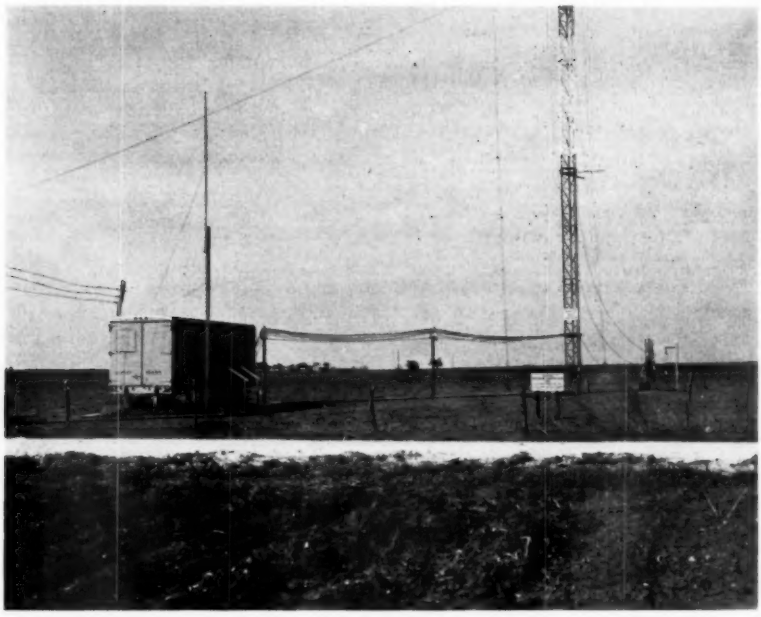


The ground station and tower of the micrometeorological station at Manor, Texas, operated by the Electrical Engineering Research Laboratory, University of Texas. Temperatures charted on page 76 were measured at the foot of the tower. Engraving from the *Bulletin* of the American Meteorological Society.

The Temperature at Your Feet

WERNER A. BAUM, ASSOCIATE PROFESSOR OF METEOROLOGY,
FLORIDA STATE UNIVERSITY

AUGUST in Burlington, Vermont, and August in Reading, Pennsylvania — quite different you say. And, judging by the 5°F difference in mean temperature, you'd be quite right. For Burlington reports a mean August temperature of 67.9°F while Reading gives 72.9°F. But it may surprise you to learn that the resident of Burlington, who no doubt is quite proud of his pleasant August, has the temperature of Reading, and of places a good deal farther south, literally right at his feet.

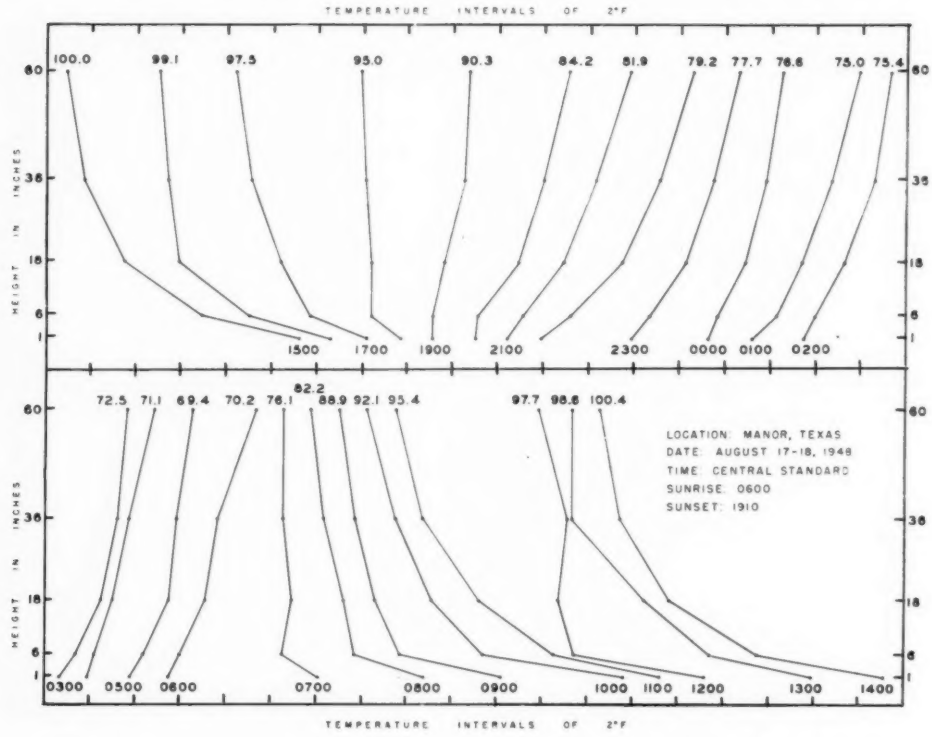
When meteorologists started measuring temperatures, they soon found that the air layer immediately above the earth's surface is a zone of disturbance. Large temperature differences over small horizontal distances exist; there are rapid fluctuations of temperature; and there are very large vertical temperature gradients. These conditions arise from the facts that the earth's surface is the primary source of heating and cooling of the air and that variations in the nature of the surface are reflected in temperature conditions of the immediately overlying air. To avoid this zone of disturbance and to obtain "representative" temperatures for synoptic purposes, thermometers are generally five feet or more above the surface.

Ordinary climatological temperature data are from thermometers thus elevated, and our normal climatology therefore pertains to the head level of human beings. Investigation of the peculiarities of the zone of disturbance falls within the realms of micrometeorology and microclimatology. Results of such investigations are of interest not only to meteorologists and climatologists but to a very di-

versified audience. For instance, plants, particularly in their critical early stages of development, generally live very close to the earth's surface; they are immobile and therefore must content themselves with the climatic conditions at a particular spot. Therefore plant ecologists are definitely concerned with microclimatology. Here we shall concern ourselves with only one aspect of this subject, the variation of temperature with height in the very lowest air layers.

Let us examine conditions during a 24-hour period last August at Manor, Texas. The chart is based on data published by the Electrical Engineering Research Laboratory of the University of Texas, conducting an investigation in micrometeorology under a contract with the Office of Naval Research. Temperatures were measured at 1, 6, 18, 36 and 60 inches above the surface by means of small rod-shaped thermistors (attached to a 300-foot steel tower), coated with a reflecting layer of aluminum paint to reduce radiation effects. Each temperature is the average of five readings of five seconds each made over an approximate six-minute period beginning on the hour. Thus the turbulent fluctuations are largely smoothed out. The general nature of the terrain for a radius of several miles around the observation site is very gently rolling, and the four-acre site itself is located on a broad rise which is nearly level for about half a mile in all directions. Most of the land in this area is under cultivation most of the year, with cotton being the predominant product. The four-acre tower site is covered with a scattered growth of Johnson grass, which is kept mowed to a height of less than four inches.

During the particular day covered by our



Vertical temperature distribution between one and 60 inches above the earth's surface, August 17-18, 1948, at Manor, Texas. The time of beginning of each six-minute period covered by the data is indicated at the bottom of the temperature-height curves. At the top of each curve is shown the 60-inch temperature in °F. Based on data published by Electrical Engineering Research Laboratory, University of Texas, under contract with the Office of Naval Research.

observations (1500 CST, August 17, 1948, to 1400 CST, August 18, 1948, inclusive) there were no notable weather phenomena. During the first two and the last four hours there were a few cumuli, but the sunshine was reported as 100 per cent of the possible throughout practically the entire period. The wind at 12 feet exceeded six miles per hour only occasionally during the first five hours, and conditions were calm from 0100 to 1000.

The beginning of each six-minute period covered by the temperature observations is indicated at the bottom of the temperature-height curves. At the top of each curve is shown the 60-inch temperature in °F. By utilizing the latter figure and the horizontal scale divisions, each corresponding to 2°F (increasing from left to right), it is possible to obtain the temperatures at lower levels, if desired.

Considering that the data represent one day only, the diurnal variation of the temperature-height relation is very clearly illustrated. The only erratic observation, perhaps associated with a concentration of clouds between the point of observation and the sun at this particular time, is at 1200. From the figure it is immediately evident that the major difference is between day and night: during the day the temperature drops sharply with elevation; during the night it increases markedly with elevation. This variation is directly attributable to the earth's surface as the primary supplier and withdrawer of heat from the atmosphere and earth. During the day, the air and soil both receive heat from the surface and, as heat flows from high to low temperatures, the temperature is a maximum at the surface and decreases both upwards and downwards. Thus heat flows in both these directions. Conversely, during the night, the surface receives heat from both air and soil and the temperature is a minimum at the surface, increasing both upwards and downwards so that heat flows *from* both these directions.

The magnitude of the vertical temperature differences is indeed tremendous, particularly during the day. Thus at 1500, the first observation, it is more than 10°F warmer at one inch above the surface than at 60 inches, the approximate level of standard observations. The temperature difference between one inch and six inches is over 4°F and corresponds to a temperature decrease of about 10,320°F per thousand feet. This rate of temperature fall with elevation is roughly 1,900 times as great as the dry adiabatic rate, the limiting rate in the free atmosphere according to classical meteorological theory. As a matter of fact, the temperature drop between one and six inches is about 550 times as great as that corresponding to constant density with elevation (neglecting moisture effects), so that there actually is denser air overlying lighter air in this shallow layer. And in the layer below one inch, the temperature drop with elevation is no doubt even more pronounced.

The typical daytime vertical temperature distribution is often called the "insolation type," being a result of solar insolation, while the typical nighttime distribution is often referred to as the "radiation type," being a result of terrestrial radiation. The time of transition from one type to the other is intimately related to sunrise and sunset. Previous investigations have led to the result that the switchover from radiation type to insolation type occurs soon after sunrise while the reverse change occurs before sunset. This result, confirmed by the data presented here, is due to the fact that the net heat gain or loss of the surface is zero sometime after sunrise and sometime before sunset, some insolation being required to balance the radiation loss by the surface. The precise time of zero heat gain or loss depends, of course, on additional factors, such as evaporation.

Detailed studies of the diurnal variation of the vertical temperature distribution show that the magnitude of the insolation type depends primarily on the time relative to sunrise and sunset and on the presence or absence of sunlight. The magnitude of the nocturnal inversion appears to depend primarily on cloud conditions and wind speed, low wind speed and absence of clouds being conducive to a pronounced radiation type of vertical temperature distribution. In the period represented by the chart, there were no clouds during the night and the air was quite still. Thus the radiation type is quite pronounced between sunset and sunrise. But even so, it is evident that the insolation type involves greater temperature differences.

Not only does the daily temperature range rapidly increase downward as we go below

the level of standard observations, but there is also a change of the mean temperature with elevation. On this particular day the mean temperature (average of the 24 values) was 85.3° Fahrenheit at 60 inches, 85.5°F at six inches, and 87.3°F at one inch, so that its value differed materially from the standard level value only in the very lowest layers. The variation of the mean temperature with height would probably have been considerably greater had the nocturnal conditions not been quite so favorable to development of the radiation type. The daily variation of mean temperature with height is well reflected in data giving the monthly mean temperature at different levels.

Such data are available as a result of a conference of experts on pasture plants, held at Rutgers University in 1941, at which microclimatic observations were suggested by Dr. Erwin R. Biel in order to solve certain problems in connection with research projects of the U. S. Regional Pasture Research Laboratory, State College, Pennsylvania. Observations were inaugurated by Dr. James W. Marvin, of the University of Vermont at Burlington.

For a period of almost five years, air temperatures at two-hour intervals (even hours) were determined at heights of three inches and six feet over clipped grass at the University of Vermont. In computing the mean monthly temperature, the mean daily temperature is defined as the average of the 12 daily observations. The table gives the correction (°F) which must be applied to the mean monthly temperature at six feet in order to obtain the corresponding temperature for three inches. Unfortunately, the months of December, January, and February cannot be utilized due to a persistent snowcover deeper than three inches, covering the lower thermometer.

From the table it is apparent that there is considerable variation in the correction factor for a given month from year to year. Also, within individual years there are minor deviations from the annual course shown in the column giving average conditions. It is clear that through most of the year, depending on the length of day and angle of the sun's rays, the insolation type outweighs the radiation type, leading to an increase of mean temperature as we go below the level of standard observations. In the midwinter months the radiation type probably dominates, giving some decrease of temperature downwards. There probably is also some increase in mean annual temperature downwards.

CORRECTION TO BE APPLIED TO THE MEAN MONTHLY TEMPERATURE AT SIX FEET TO OBTAIN THE CORRESPONDING TEMPERATURE AT THREE INCHES, °F, (BURLINGTON, VERMONT)

	1942	*1943*	*1944*	*1945*	*1946*	*1947*	*Av.*
March	—	—0.6	—	2.8	0.8	0.2	0.8
April	—	1.5	2.6	2.6	1.1	2.2	2.0
May	—	4.3	2.5	4.6	1.4	2.7	3.9
June	—	6.2	4.5	7.6	3.6	—	5.5
July	—	4.4	8.0	6.4	3.4	—	5.5
August	4.9	4.8	8.8	—	2.4	—	5.2
September	1.7	4.6	4.5	—	1.9	—	3.2
October	0.2	0.9	1.6	—	0.6	—	0.8
November	0.5	1.5	0.4	—	0.2	—	0.6

The significance of this vertical variation of the mean temperature is enhanced by the fact that it is largest in summer when the horizontal temperature gradients at the standard level are smallest. As the summer horizontal temperature gradient in the northeastern United States is of the order of 1°F per degree of latitude, a 5.5°F vertical difference between three inches and six feet is the equivalent of a horizontal difference of about 380 miles at the standard level!

Returning now to our resident of Burlington, it is clear that at his feet he has a mean August temperature corresponding to the reported mean temperature of Reading. At levels even lower than three inches, he probably has an August mean temperature typical of our southland. Thus, within inches we have temperature differences normally thought of as occurring over hundreds of miles.

One major moral of this story: Remember the limitations inherent in our standard climatic data!

HEAT BLAST

Temperatures soared to 158°F on the central coast of Portugal during a two-minute heat blast on July 5th, according to press reports. The area around Figueira reported much illness among humans and many deaths among cattle and poultry. WEATHERWISE is seeking further information from official sources. A heat wave of severe proportions had sent temperatures to record heights on the Iberian peninsula, with Seville at 125°.

Air Weather Service reserve officers arriving at Kindley Air Force Base, Bermuda. From top to bottom are Officers Jessup, Visscher, Magar, Johnson, Osmun, Bassidy (who accompanied the group to Bermuda), Jenner, Ludlum, Bassett, Touart, Sharp, Coveney, Kappler, Daley, and Rummel. Official USAF photograph.

Reserve Officers Tour North Atlantic Bases

AN ACTIVE DUTY training tour to Air Force bases in the North Atlantic recently brought 14 Air Weather Service reserve officers together again for a two weeks period from June 5th to June 19th. First host to these returning officers was the 373rd Weather Reconnaissance Squadron, Very Long Range, stationed at Kindley Air Force Base, Bermuda. Lectures and demonstrations were given by squadron officers to explain the mission of the 373rd. There was opportunity to study the problems of routine weather reconnaissance firsthand by participating in the 14-hour flights over the North Atlantic on the squadron's RB-29's.

The second week was spent with the 2108th Air Weather Group, with headquarters at Westover Air Force Base, Massachusetts. Here the problems confronting Arctic as well as North Atlantic weather work were studied. Flights were made in MATS aircraft to Mignan, Quebec, Harmon and McAndrews Air Force Bases in Newfoundland, and Goose Bay, Labrador. The worldwide strategic weather central network was studied.

The tour was only one aspect of a rapidly developing training program of the Air Weather Service to keep reserve officers abreast of current observing and forecasting techniques.

Typical seismograph equipment for recording microseismic data at a station established by the U. S. Naval Aerological Service.

HUNTING HURRICANES WITH THE SEISMOGRAPH

MARION H. GILMORE, GEOPHYSICIST.
NAVY HURRICANE WEATHER
CENTRAL, MIAMI, FLORIDA

THE seismograph was invented more than 2,000 years ago to make permanent records of major earthquakes, but these early instruments were never successful because of crude design and workmanship. It was not until 1841 that an instrument worthy of the name "seismograph" was developed. Since then, instruments for measuring extremely small movements in the earth's solid crust have kept pace with the development of the science of geophysics. Modern seismographs are useful in many fields other than that of locating the centers of major earthquakes. They have been and are being used for such varied purposes as locating and mapping underground geological structures that could contain oil or other valuable minerals; locating the sites of big guns from ground vibrations; locating the center of blasting activity; studying the effects of vibrating machinery and earthquakes on nearby buildings, bridges, and dams; measuring the periods of oscillations of the ground and buildings; and in detecting, locating, and tracking hurricanes and typhoons.

There are probably a million earthquakes annually over the earth, but most of them are so small that a seismograph at one location can register only a few. If the records from any seismograph station are examined carefully, however, they show that the earth is in a constant state of agitation. The greatest part of all records, that between the earthquakes themselves, is literally filled with vibratory motions. Sample traces of a few typical earth motions, Fig. 1, show fairly regular vibrations passing through the earth's crust. Oscillations of this kind are called microseisms and can be found on all seismograph records. The microseisms in the top group of Fig. 1 are more numerous than all other types combined and seldom get large. It is generally agreed that such vibrations in the earth are caused by purely local conditions such as traffic, heavy surf, and wind blowing on trees and buildings. Similar microseisms are also found in the bottom group, together with a good example of a distant earthquake.

The microseisms in the second and third groups are of most value to meteorological study because, for the past 50 years, geophysicists have noted a very good correlation between them and severe storms over the oceans. They often increase in size to as much as 20 times normal, representing a corresponding movement in the earth's crust of at least 1/1,000 inch. This large movement in a solid foundation makes astronomical observations and the timing of the first phase of an earthquake more difficult. These vibrations pass through the earth's crust with speeds slightly greater than 100 miles per minute, with a distance of three to six miles between wave crests. The tendency for microseisms to increase rapidly in amplitude, to remain high for a few hours to several days at a time, and to develop into more or less regular beats of approximately one minute duration (Fig. 1), caused them to be a popular topic for discussion by seismologists. A group of geophysicists, led by Father James B. Macelwane, S.J., maintained that abnormal microseismic activity was caused directly by sev e storms over the oceans. Father Mace' ane was the first in this country to make a direct attempt to determine the cause and source of this abnormal microseismic activity, which he did by initiat-

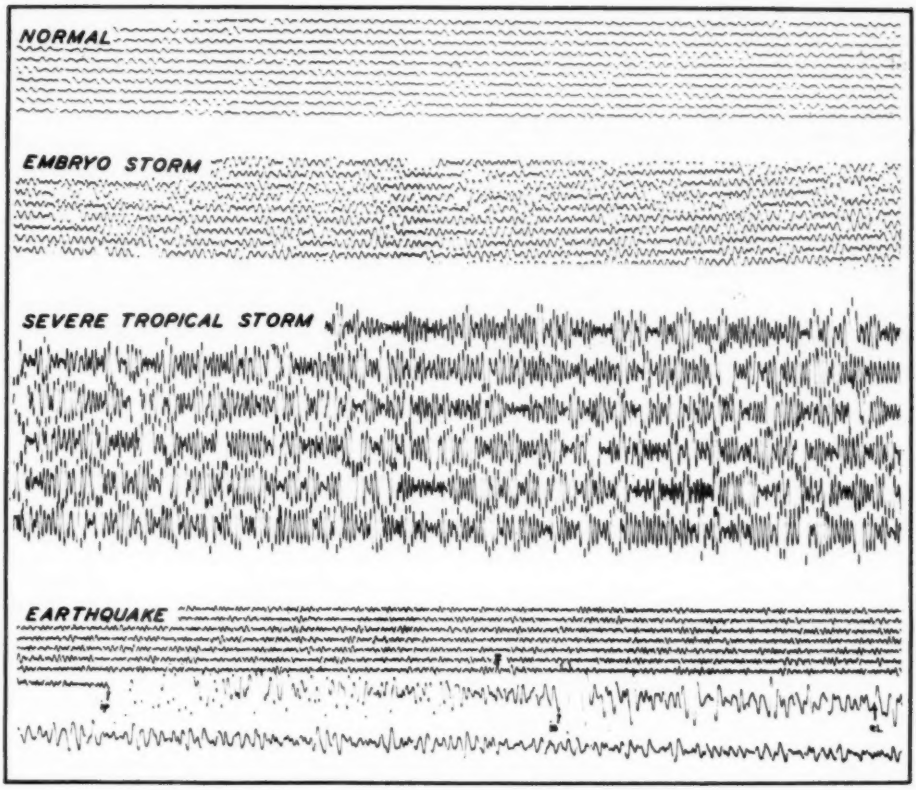


Fig. 1. Types of earth vibrations, showing a normal microseismic trace, microseisms increasing in amplitude due to an embryo storm, large microseisms caused by a severe tropical storm within range of the recorder, and a normal trace suddenly disrupted by seismic waves from an earthquake in Liberia, Africa (5,900 kilometers from the recording station in Puerto Rico).

ing a research project at St. Louis University in 1938. This project was developed by Father Ramirez, S.J.

This first tripartite microseismic station in the United States consisted of three instrument vaults, one at each vertex of a triangle, equipped with sensitive seismographs capable of magnifying the small microseisms about 5,000 times. Father Ramirez calculated the direction of propagation of many different microseismic waves in 1938. The results obtained during the severe September hurricane were very good. The first bearings calculated pointed toward the storm when it was southeast of St. Louis. Then they gradually shifted to the east, then northeast, as the hurricane passed northward up the Atlantic Coast and over Long Island. These results greatly strengthened the theory, and the potential value of such information to forecasting led the U. S. Naval Aerological Service, under the direction of Captain H. T. Orville, USN, to initiate a major research project in 1944 to determine the actual operational value of microseismic data to military forecasting units.

In the research conducted by the Naval Aerological Service, the distance between the vaults of a tripartite station was reduced from nearly four miles to less than one-half mile, and a central recording building was added, located 1,000 feet from each of the three vaults. Two sets of three sample microseismic records are shown in Fig. 2 for vaults A, B, and C of a tripartite station. The amplitude of the microseisms, with the

two exceptions noted below, is directly proportional to the intensity of the storm and its distance from the station. Therefore, if the distance of the storm is known, it is easy to judge its intensity by the increase or decrease of the microseisms. Hurricane forecasting stations keep a current record of the amplitude of the microseisms from the several stations, and as soon as any station shows an abnormal increase in microseismic activity, the whole area around it is carefully inspected before releasing a forecast. Usually the tripartite stations can obtain bearings on the storm or suspicious area, and thus narrow the search.

As soon as abnormal microseismic activity begins at any station, it is important to know immediately the direction from which it is coming. By necessity, any type of wave traveling in the earth's crust, as it passes a tripartite station, must strike one instrument site or one side before reaching the remaining part of the triangle. It is possible, therefore, to calculate the direction of propagation of a wave by carefully measuring the difference in arrival time of the crest of a wave at each of the three station sites. The sample records in Fig. 2 show several sets of straight lines drawn through the microseismic trace. Each line in a set passes through the beginning of a time break in one of the three traces, noted by a rectangular

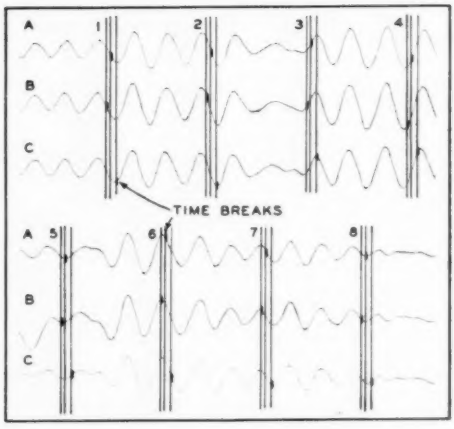


Fig. 2. Storm microseisms as recorded at stations A, B, and C of a tripartite station. Note how the simultaneous time breaks recorded on the traces for the three stations intersect different portions of the wave.

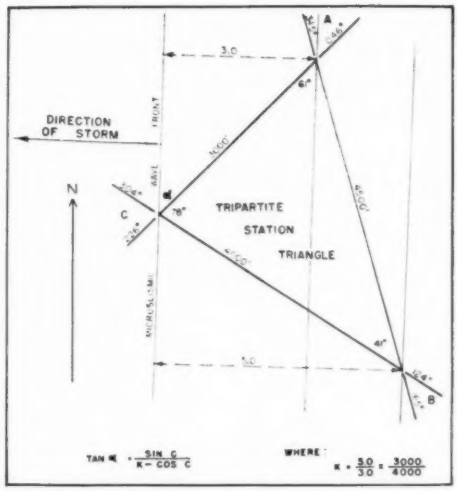


Fig. 3. The trigonometric relationships involved in the tripartite station triangle. If the formula given is solved, the angle α is found to equal 43°, with the direction of the storm 273°.

mark in the trace. The corresponding line in the next set of three is exactly 15 seconds later. All the time breaks in any one set were made mechanically at exactly the same instant. Examination of the traces shows that the time breaks are on different portions of the wave, because the wave was actually moving across the station site when the simultaneous time marks were made. Each time break on the C trace is farthest to the right, which means that the wave reached that station first. In like manner, A was

TABLE OF TIME DIFFERENCES

	1	2	3	4	5	6	7	8	Av.
C-A	3.0	2.8	3.1	3.3	3.2	3.2	2.8	2.8	3.0
C-B	5.0	4.9	4.8	5.0	5.2	5.2	5.0	4.8	5.0
A-B	2.0	1.9	1.8	2.0	1.9	2.1	2.2	2.0	2.0

next and B last. The arrival time differences can be determined accurately by measuring the intervals between the vertical lines of each set. Such measurements are recorded in the table of time differences, and the average of each group used in the calculation formula in Fig. 3. A straight line is drawn through station C to represent the wave front striking the first station. Its exact slope through C was determined by the ratio of time differences between CA and CB, or 3.0 to 5.0. It was then a simple problem

in trigonometry to find the angle that the wave front made with the side CA of the triangle. Since the slopes of all sides of tripartite station triangles have been determined by survey, the direction toward the storm is easily computed.

When the Navy's microseismic research project was started, little was known about what operational and theoretical problems would have to be met. Since the first work in 1944, many operational problems have been solved, including such things as determining best station size, and improving instrumental techniques and instruments. This phase of the project is continuing. On the theoretical side, it was soon learned that "microseismic barriers" existed in both the Caribbean and Pacific, through which microseisms cannot pass or through which only a small percentage of the wave can pass. One major barrier in the Caribbean extends from a point south of Antigua to just north of Puerto Rico, thence along a line between Key West and Cuba. To overcome the loss of data caused by such a microseismic barrier, it is necessary to operate tripartite stations on both sides of the zone.

In addition to the barriers, it has been found that a storm will not produce any abnormal increase in microseismic activity when it passes over water of a depth under about 20 feet. There is a large area in the Bahamas where the water is less than that depth, which causes a "blind spot" in the seismograph network.

In spite of such limiting factors in the Caribbean, and to a lesser degree in the Pacific, it is still possible, geographically, to have an adequate network of microseismic stations to cover the whole hurricane and typhoon belt. As data accumulate, the barriers are being closely delineated. When this is finally done, it then becomes mainly a problem of locating stations in such a way that simultaneous recording of a storm by two stations is always possible — regardless of the storm's location. The Navy's microseismic project is now working on this problem by testing various sites and adding some new stations where further valuable data may be obtained. Even though there are still problems to be solved, the Navy's research to date has led to the point where a microseismograph recording unit, such as that on page 80, can register the small vibrations caused by a storm. From this recording, an experienced observer can tell something of the intensity of the storm by the increase or decrease in the microseismic amplitude; he can calculate the direction of the disturbance from any one tripartite station; and he can forecast many characteristics of the storm by the shape and period of the microseisms. Five years of research have transferred the subject of microseismic storm detection from the realm of the academic into the category of applied science. The project is continuing and, although still classed as research, it is actually an integral part of the operations of hurricane forecasting units. Research will soon be extended to include a study of extra-tropical storms.

SIR NAPIER SHAW COMPETITION

To commemorate the work of Sir Napier Shaw, two meteorological contests are being conducted in 1949 by the Royal Meteorological Society. One is open to juniors, aged 15 to 21, and the other to seniors who are not professional meteorologists. Junior contestants are urged to submit "the best description of any weather phenomena actually witnessed at any time by the entrant. The description should be as short as possible and in any case less than 1,000 words in length, and if possible should be illustrated by a sketch or photograph." All material should be forwarded to the Royal Meteorological Society before October 15, 1949. For further information and the senior rules, those interested in entering should write to Robert N. Culnan, c/o U. S. Weather Bureau, Washington 25, D. C., requesting a copy of the rules and instructions for the Sir Napier Shaw competition.

BALLOONISTICS IN THE PACIFIC

A rawinsonde balloon was recently tracked to 122,661 feet by the 20th Weather Squadron of the U. S. Air Force at the Handa Air Force Base, Japan. The standard computation tables can be utilized up to that height, which is the five-millibar level. The eager trackers of the balloon, however, were reluctant to cease their record effort and continued to follow it to 133,500 feet, where the balloon was observed to burst.

AIR FORCE'S RB-29
"HURRICANE HUNTERS"
TRACKS SEASON'S FIRST
AUGUST 26 TO SEPTEMBER 3, 1948
TURNING POINT NO. 3
TURNING POINT NO. 2
POINT ALONG TRACK OF MINIMUM BAROMETRIC PRESSURE AND MAXIMUM WIND VELOCITY
TURNING POINT NO. 4
TURNING POINT NO. 1
TYPE OF TRACK USED BY 373RD "HURRICANE HUNTERS" TO PENETRATE STORM AND LOCATE "EYE" (DETERMINED BY INTERSECTION OF PERPENDICULARS ERECTED AT POINTS OF MINIMUM BAROMETRIC PRESSURE)
BERMUDA
(373RD RECONNAISSANCE SQUADRON, V.L.R., WEATHER)
KINDLEY AIR FORCE BASE
1 AUGUST 26TH 4.45 AM (EST) HURRICANE LOCATED BY AIR FORCE B-29
2 AUGUST 27TH 4.45 AM (EST) HURRICANE MOVING NORTH WEST AT 18 MILES PER HOUR
3 AUGUST 28TH 2.10 AM (EST) A B-FORCE B-29 PENETRATE HURRICANE FOR 5TH TIME. THE EAST COAST IS ALERTED
4 AUGUST 29TH 8.30 PM (EST) FORWARD SPEED OF HURRICANE INCREASED TO 10 MILES PER HOUR
5 AUGUST 30TH 4.00 AM (EST) STILL MOVING NORTHWEST. EAST COAST FEELING EFFECTS OF HURRICANE'S 100 MILE WINDS
6 AUGUST 31ST 7.30 PM (EST) VEERING NORTH AWAY FROM COAST. CONTINUED STRONG WINDS
7 REACHING COLDER WATER WINDS BEGAN TO LESSEN AND AREA OF STORM INCREASED. CONTINUING OUT AT SEA. HURRICANE FORCE DIED OUT OFF GREENLAND ON SEPTEMBER 3RD
SAVANNAH
MIAMI
AIR FORCE WEATHER BUREAU JOINT HURRICANE WARNING CENTER
NASSAU
KEY WEST
BAHAMAS

The above chart shows the "track" of last season's first hurricane, which developed northeast of the Lesser Antilles on August 26, 1948, and dissipated off Greenland on September 3rd. An average of two flights were made from Kindley Air Force Base, Bermuda, during each day's activity, with approximately 12 radio reports made to the Miami Joint Hurricane Warning Center in the course of each flight. Air Weather Service chart.

Boxing the Hurricane

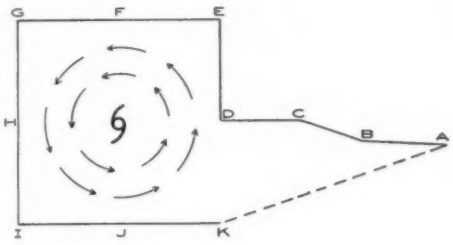
Air Force Procedure for Tracking Tropical Storms

BEGINNING with the season of 1948, the Air Weather Service "Hurricane Hunters" of the 373rd Reconnaissance Squadron, Kindley AFB, Bermuda, adopted a new "boxing" system for penetrating hurricanes. This method, consisting of making certain measurements and computations from positions along the storm's outer edge, has made it unnecessary for the huge RB-29's and their crews to make the hazardous flight into the eye of a hurricane in order to determine its position and intensity.

In the "boxing" procedure, the storm area is approached on a track leading directly toward the predicted position of the storm center. This track is maintained into a full cross wind from the left (in the Northern Hemisphere, hurricane winds blow in a counterclockwise direction) until winds of hurricane force (75 miles per hour) are met. The position at which hurricane winds are encountered is the midpoint of the base side of a square or rectangular pattern to be flown around the storm. At this point a new track,

90 degrees to the right and directly downwind, is assumed and held until the position is reached where the second leg, 90 degrees to the left, will be taken up.

The lengths of the sides of the box are determined by the observer so that each leg is started at a point which will place that leg far enough from the center of the storm



BOXING THE HURRICANE

A. B-29 departs base.

B. Course changed to intercept hurricane.

C. Course changed again upon late reports of hurricane center position.

D. Winds of hurricane strength experienced: right-angle turn made.

E. Winds have decreased to point where a turn can be safely made; right-angle turn puts plane on second leg.

F. Point of lowest pressure observed and perpendicular toward center of storm erected.

GH & IJ. Operations at E and F repeated to complete the box.

K. Mission accomplished: plane returns to base.

that visual contact with the ocean at 1,500 feet may be maintained. The lengths of the legs will vary with the structure of the storm. Experience has proven that boxes with sides varying in length from 120 to 150 miles are practical for storms in the area below 35° north latitude. Above that latitude the storms usually become more widespread and necessitate tracking of much larger box patterns. On the second, third, and fourth legs, all flown to the left so as to maintain the storm center off the left wing, continuous barometric pressure readings are made and the positions of lowest pressure values are recorded. Perpendiculars, plotted from these positions, intersect at the position of the storm center, and thus the hurricane eye is charted. During the flight, complete observations are made at the four corners and centers of the sides of the boxlike pattern, and at any other position the observer considers to be of value.

This method of surveying a hurricane has many advantages over the previous system of actually penetrating the eye, in that it:

1. Enables greater accuracy in plotting the hurricane since it permits more accurate navigation within the storm area with benefit of electronic aids. While flying near the storm center, radio reception is nullified by static electrical interference.

2. Provides an actual measurement of the area of hurricane disturbance extending in all directions from the eye. More effective observations are made in all quadrants of the storm.

3. Substantially decreases the strain on the aircraft and crews. Flight in the vicinity of the eye is normally extremely turbulent.

The maximum intensity of the hurricane winds can be calculated from the estimated distance to the eye from the perimeter of 75-knot winds. In general, the greater the distance the greater the force of maximum winds.

The entire track is flown at low altitude (1,000 to 1,500 feet) in order to permit the weather observer to estimate wind velocities by visual contact with the disturbed ocean surface. Celestial, loran, direction-finding, and radio-range systems are used for navigation whenever possible.

During flight, observational data of the hurricane's position and intensity are sent by radio directly to the Joint Weather Bureau-Air Force-Navy Hurricane Warning Center at Miami, Florida.

DROPSONDE TO BE USED TO STUDY EYES OF HURRICANES

Extensive tests of the new Air Force dropsonde will be made during the 1949 hurricane season by the 373rd Reconnaissance Squadron. Releases will be made from an RB-29 at approximately 33,000 feet, and a parachute will carry temperature, humidity, and pressure instruments down into the eye of the cyclonic whirl. Recorders aboard the plane will enable the observers to make a complete vertical sounding at little risk to plane or personnel.

FORECASTING THE WEATHER

The Weather Types of North America — 4

ROBERT D. ELLIOTT
AMERICAN INSTITUTE OF AEROLOGICAL RESEARCH

SO FAR in this series of articles on North American weather types only one zonal flow type, type **B**, has been described. In this issue three more zonal flow types will be depicted by diagrams and described.

In zonal flow types there are no outstanding persistent upper-level crests and troughs such as appear in the meridional flow types, although small ones do exist. Differences between zonal flow types are measured primarily by the degree of southward shift of the zone of the westerlies aloft, and the corresponding shift in the mean storm tracks. Accompanying this southward shift there appears at the surface a band of high pressure areas at high latitudes composed of extremely cold air in the lower levels.

The mildest zonal flow type, the one where the cold highs are least developed, and in which, therefore, the belt of upper-level westerly winds is in the northernmost position, is the **B** type. The sequence of types corresponding to successively greater southward displacements of the westerly belt is as follows: **B, E**L, **E**M, **E**H. A measure of the degree of southward shift is the mean latitude at which the low center passes 105° west longitude (where it crosses the Rockies).

The table below indicates these values:

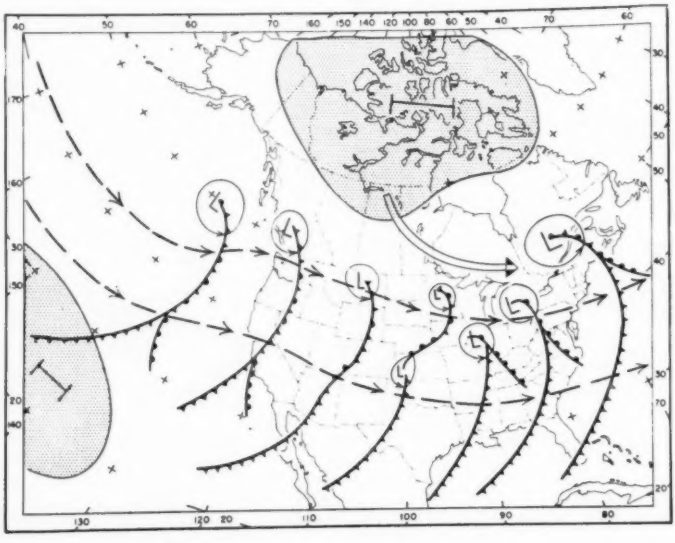
Zonal Flow Type	*Latitude of Low Center Trajectory at 105° West*
B	59° north
*E*L	47° north
*E*M	40° north
*E*H	34° north

From this table it is evident that the heavy precipitation belt will be shifted farther south as one proceeds from **B** type toward **E**H type. Likewise, the belt of low temperatures north of the low trajectory is shifted southward as one proceeds in the same manner.

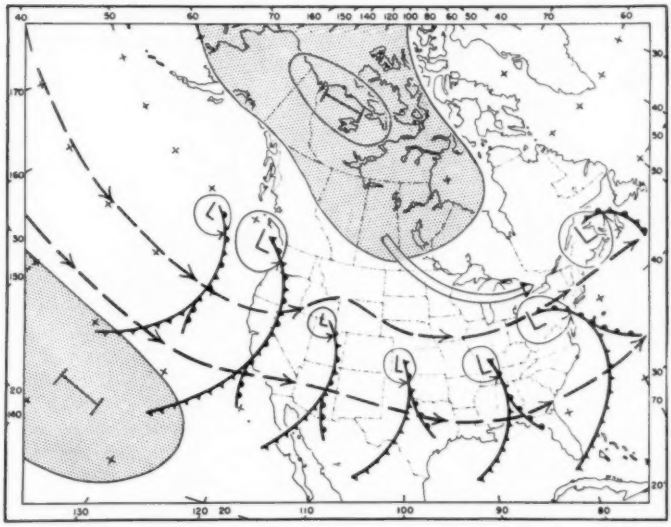
As in the preceding issues, the types are represented by schematic diagrams, each diagram covering the number of days required for one cyclone to advance eastward across North America. The mean upper-level flow for each type is indicated by dashed lines and arrows. Areas of persistent high pressure are delineated by stippling and double arrows indicate trajectories of major polar outbreaks. Successive daily positions of a single cyclone and its associated frontal system are shown in conventional weather map fashion.

The descriptive material pertains to the winter

TYPE E$_L$ OF NORTH AMERICAN WEATHER TYPES



TYPE EM OF NORTH AMERICAN WEATHER TYPES



season. Type characteristics vary only slightly with season and the well-known seasonal climatic differences are primarily the result of seasonal variations in the frequencies of occurrence of the types.

TYPE EL

This is a zonal flow type and is characterized by a slight southward shift from normal of the upper-level westerlies.

At the surface, a cold continental high, persistent but not very intense, is present in northern Canada and Alaska. The low enters the Pacific Coast near the 50th parallel and advances eastward, dipping a little south after crossing the Rockies. A considerable amount of warm tropical Pacific air is drawn up to the West Coast ahead of the low. This accounts for the heavy precipitation which occurs there. In the course of the passage of the low across the Rockies a wave often develops along the frontal zone, becoming a major storm east of the Rockies, where warm moist tropical Gulf air is drawn into the new warm sector. This storm follows a northeastward-directed trajectory across the eastern part of North America. When the air to the north of the trajectory is exceptionally cold, the westerlies aloft are strong and the low moves eastward more rapidly than indicated on the map opposite. In this case there is no wave development to the south of the low.

Precipitation averages above normal throughout nearly all of the United States and most of southern Canada, largest anomalies occurring along the storm trajectory. This is definitely the "wet" type.

Polar Pacific air dominates the United States and the only outbreak of cold continental air moves primarily eastward into eastern Canada. Therefore temperatures average generally above normal throughout the United States, but in Canada, where cold polar continental air is the rule, temperatures are generally below normal.

As might be expected, this type occurs most frequently during the winter half of the year.

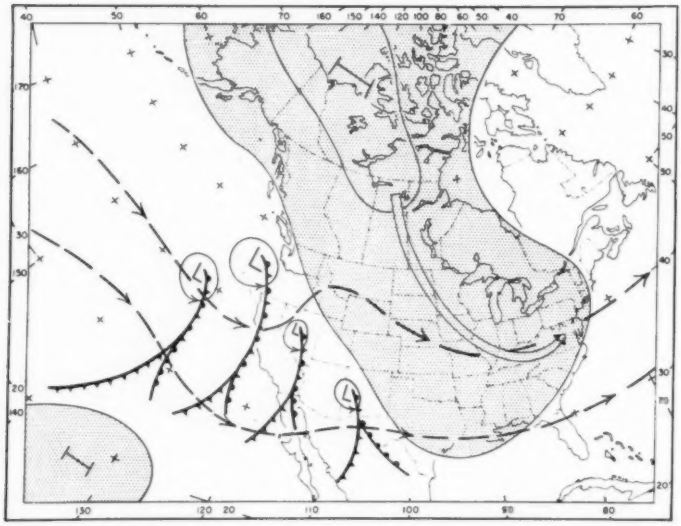
TYPE EM

This is a zonal flow type in which the upper-level pattern shows only minor troughs and crests. The upper-level westerlies are displaced a moderate distance south of normal over a very broad sector extending at least from the East Coast to the mid-Pacific.

At the surface, there is present in Alaska and northwest Canada a persistent high pressure center with a central pressure of 1030 to 1040 mbs. The cyclone, as it approaches the West Coast, reaches maximum intensity just off the coast at 45° to 50° north. A frontal zone moving on inland carries along, or develops, a new cyclonic center in the Great Basin, which then moves on east-southeastward to the Appalachians, where the storm deepens rapidly and commences to move northeastward. Along most of this path the storm center is being continually pressed southward by the mass of cold polar Canadian air to the north, and a moderate outbreak follows the low into the Great Lakes and New England regions.

Precipitation is rather widespread in this type, although not as much so as in the case of type EL. Precipitation is above normal along the West Coast of the United States, especially so

TYPE E_H OF NORTH AMERICAN WEATHER TYPES



in northern California, but is below normal in Canada. A band of above normal precipitation is experienced in a zone extending from the Gulf states along the Appalachians to New England, because tropical Gulf air is drawn into the deepening and recurving storm along this portion of its path. Elsewhere precipitation is near normal, excepting in the northern Great Plains area and western Canada, where the high pressure area maintains clear cold weather.

Temperatures are below normal in Canada and the northern Great Plains and Great Lakes regions. Elsewhere temperatures are near or above normal.

This type occurs most frequently in the late winter and early spring.

TYPE E_H

This is a zonal flow type, characterized by an extreme southward shift of the belt of upper-level westerlies over a broad sector from at least the East Coast to the mid-Pacific.

At the surface, a tremendous high centered in Alaska and northwest Canada, and having a central pressure of 1040 mb or more, extends southeastward over most of the North American continent in much the same manner as the Siberian high covers a great part of Asia. The weather is completely dominated by this high, which forces storms entering the West Coast (at low latitudes even over the ocean) to squeeze southward around the southern periphery of the high. In doing this they weaken and usually completely disappear from the surface weather chart before reaching the Gulf of Mexico. As a result, an abundance of precipitation occurs along the southern part of the West Coast but ceases over the Great Basin, and clear cold weather is the rule through the rest of the United States and Canada.

Precipitation is above normal in California and Oregon and near normal in the Great Basin. To the east precipitation is mostly below normal.

Temperatures are generally below normal, especially in the northern Great Plains and the prairie provinces of Canada, where weather is colder than that experienced with any other type.

Type E_H is a midwinter type, but has occurred as early as November and as late as May.

NEW RESEARCH ROCKET

Not all rocket development is being made with strictly military purposes in mind. A new pencil-shaped rocket for exploring the meteorological mysteries of the stratosphere has recently been tested by the United States Navy. It is known as the **Aerobee**, and was designed as a research instrument. It is much lighter and cheaper to operate than the military V-2 rockets.

The **Aerobee** is approximately 20 feet long, but only 15 inches in diameter; it weighs 1,665 pounds. It has reached a speed of 4,100 feet per second in about 45 seconds, and has attained an altitude of over 70 miles at the White Sands Proving Ground in New Mexico. The instruments carried aloft can vary according to the purpose of the flight. Meteorologists hope to get valuable data on the composition of the atmosphere at high levels.

WHEN SUMMER ENDS

S. S. VISHER

PROFESSOR OF GEOGRAPHY
INDIANA UNIVERSITY

IN WEATHERWISE for June, the average dates on which summer commences on various bases were presented, with three maps. Here four average ending dates for summer are given. These are supplementary to the calendar specification that summer ends with the month of August, and to the astronomical declaration that it ends with the arrival of the autumnal equinox. The latter event occurs at 3:06 a.m., Central standard time, September 23rd, this year.

If summer is defined as the quarter-year having highest average temperatures, according to Fig. 1 it ends in the last week of August in approximately the southern half of the United States and also west of the Rockies.

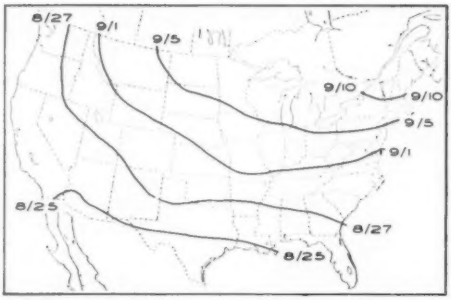


Fig. 1. The dates on which summer normally ends if it is the warmest quarter of the year.

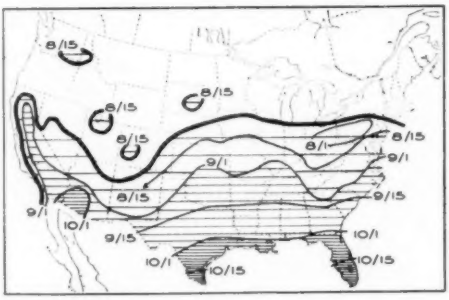


Fig. 2. The dates on which "hot summer" ends (daily normals 75° or higher).

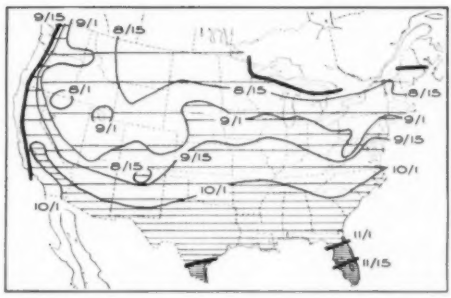


Fig. 3. The dates on which daily normals fall below 68°.

It ends during the first week of September in most of the remainder of the country, except in northern New England, where the date averages September 10th.

If summer is defined as the season in which daily normal temperatures are 75° or higher (average of day and night), it terminates in the last half of August in a wide middle zone (see Fig. 2), but it closes in September in much of the South and not until October near the Gulf of Mexico. Such heat is not normal in most of the North. Indeed, where and when it occurs, it is classed as "hot summer."

If summer is the season having average temperatures above 68°, a temperature often considered to indicate summer conditions, it ends normally in August in the North (Fig. 3), in September in a middle zone, in October in most of the South, but not until November in most of Florida and in southern Texas. Daily normals of 68° are lacking in

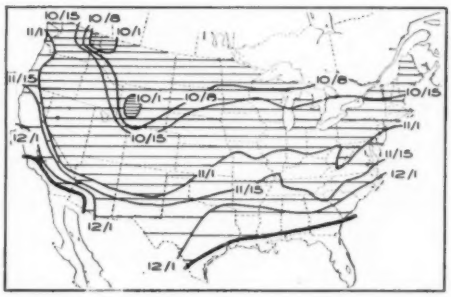


Fig. 4. When "Indian summer" ends (daily normals fall below 50°).

(Continued on page 91)

The Northeast Dry Spell of June, 1949

PHILIP F. CLAPP, EXTENDED FORECAST SECTION
UNITED STATES WEATHER BUREAU

THE LONG DRY PERIOD of June, 1949, affected the northeast portion of the United States from New Jersey and northern Virginia to Maine, and westward from the Atlantic seaboard to the eastern Great Lakes area. It resulted in many record-breaking numbers of days without rain, such as those at Washington, D. C., and New York City, and was very damaging to crops throughout the entire region.

As in the case of most unusually protracted weather abnormalities, it was a phenomenon which was reflected in the weather circulation and associated anomalies throughout most of the Northern Hemisphere. For example, with it was associated the hot dry weather in western Europe.

Despite the widespread character of these circulation features, they actually set in rather suddenly and with very little advance warning. As nearly as can be determined at the present time, the most obvious preceding feature of the circulation was a large blocking high located in the region between Greenland and Iceland during the last half of May. As is usual in well-marked blocking cases, an area of rising pressure moved westward from Greenland, causing the development of another large warm high in northeastern Canada in the latter part of May that seemed to join with and intensify an upper-level ridge of high pressure which moved into the eastern United States. At first, while the blocking feature remained in eastern Canada, the air in the United States ridge was relatively cold, being made up of cool polar air masses which were forced far south of their normal track. Therefore, the last few days of May were cool and dry in the Northeast. As the blocking continued its westward motion into northwestern Canada and Alaska, the eastern United States ridge broke off from it and became quickly transformed into a warm high, persisting until the last of June. The exact reason for this series of events is not known. Since the polar outbreaks during the last few days of May were extremely deep for that season of the year, it seems reasonable to suppose that they should become transformed by subsidence into an unusually intense warm high.

The average monthly 700-mb circulation pattern for June and its associated weather anomalies are shown in Figs. 1 and 2. The warm dry areas in the Northeast are associated with strong ridge conditions where the 700-mb contour level is 180 feet above normal, and there is a more than normal southerly flow in the Mississippi Valley. The relatively cool moist regions in the southern and central portions of the country are associated with persistent cyclonic flow and in the western plains and eastern plateau with trough conditions where the 700-mb heights are below normal.

This relationship between circulation patterns and weather follows the general rules which have been known for some time. Thus, the strong anticyclonic conditions in the Northeast prevent rainfall by shunting storms either to the

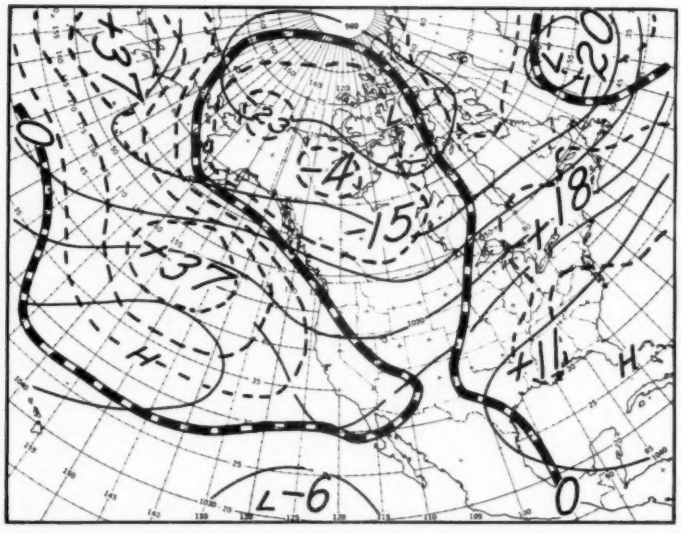


Fig. 1. Observed mean 700-mb chart for June, 1949. Solid thin lines are 200-foot contours. Heavy dashed lines show departure from normal of 700-mb height, 100-foot intervals, with centers marked in tens of feet. USWB diagram.

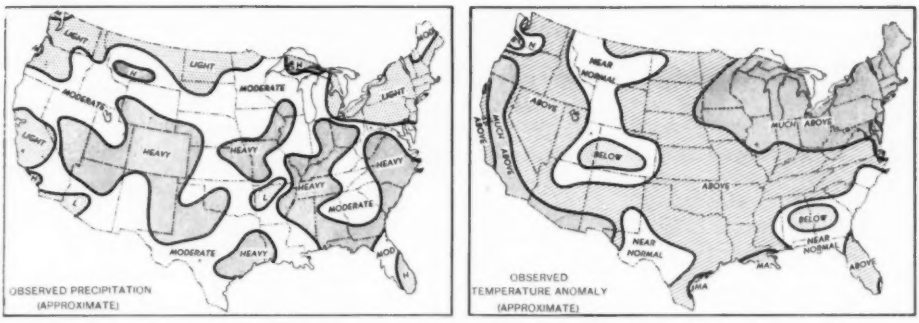


Fig. 2. The chart on the left shows the observed monthly precipitation anomaly for June, 1949. The classes light, moderate, and heavy occur on the average one third of the time. On the right is shown the observed monthly temperature anomaly for June, 1949. The classes above, below, and near normal occur on the average one fourth of the time, and the classes much above and much below occur one eighth of the time each.

south or to the north. During the greater part of June there were only two or three frontal passages across the northeast Atlantic Coast of the United States, and these were of the dry variety. Strong anticyclones are also accompanied by subsidence or slow sinking of air at high levels, which brings drier air down from aloft and creates subsidence inversions. Both of these factors prevent the development of afternoon thundershowers.

Before we close this brief discussion, attention should be called again to the large-scale character of the circulation anomalies. Thus, an unusually strong ridge may be seen over the Pacific Ocean (heights, 370 feet above normal). This is associated with a well-developed trough-ridge system over the United States, a deep trough over the Atlantic (200 feet below normal), and another strong ridge over northern Europe and the northeast Atlantic, which is not shown in Fig. 1. Thus we get the picture of a series of unusually strong waves of large amplitude and long wave length superimposed on the circumpolar westerly flow. It is clear from this that forecasts of long-period anomalous weather conditions must be based on a careful study of the entire Northern Hemisphere circulation.

WHEN SUMMER ENDS

(Continued from page 89)

two small northern areas and also close to the Pacific Ocean.

"Indian summer" is much appreciated, but is ill-defined. If its termination is when daily normal temperatures fall below 50°, it ends in October in most of the country (Fig. 4), but in November in a southern zone.

Thus, these four maps show that summer ends before September arrives in some parts of the country, on some bases, but not until much later on other bases. Even "hot summer" ends after the autumnal equinox near the Gulf of Mexico, while "summer" closes after that date in approximately the southern third of the country. "Indian summer" ends in much of the North two or three weeks after the equinox, but in the South it lasts some weeks longer.

These maps are original with the writer, based on abundant official data.

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The Wet Bulb Without Tables

F. GRAHAM MILLER

METEOROLOGICAL DIVISION

DEPARTMENT OF TRANSPORT, CANADA

THE TITLE of a well-known book, **French Without Tears,** irresistibly suggests a hybridization with "The Wet Bulb Without Tables"! The possibility of evaluating the dew point or the relative humidity without tables, from easily remembered formulas, seems attractive for some purposes, a few of which will be suggested later. By way of introduction, the wet-and-dry-bulb psychrometer will be briefly described, and some definitions reviewed.*

The wet-bulb thermometer is an ordinary thermometer, the bulb of which has been covered with a single thickness of muslin, tightly stretched and secured with a wrapping of thread around the neck of the thermometer bulb. Some other similar covering may be employed. In use, the covering must be glistening wet with pure water, which may either be applied a few minutes before the reading, or supplied through a wick about three to six inches long, of cotton or rayon yarn, from a reservoir in which the water level is at about the same level as the wet bulb. The wet-bulb thermometer is paired with a similar thermometer without accessories, the dry bulb. The two thermometers must be subjected to a wind or artificial draft of more than four miles per hour, but preferably not over 20 miles per hour. Draft may be assured by mounting the thermometers in a sling, to be whirled with a wrist movement; or ventilation may be otherwise provided. The amount by which the wet-bulb reading is lower than the dry is called the depression of the wet bulb. When ventilation of a psychrometer has been begun, the depression will soon tend to become constant, in spite of any changes in the separate thermometers. Once two successive readings a minute or so apart show the same difference, the readings should be accepted.

The maximum concentration of water vapor which can exist near a free water surface increases as the temperature rises. If a space contains all the vapor it normally can at a given temperature without the formation of dew or fog, saturation is said to exist. There are several ways of expressing the degree of humidity, and of these dew point and relative humidity are the commonest. If unsaturated vapor is cooled but its state not otherwise changed, the temperature at which dew or fog will normally begin to form is called the dew point. The difference between the actual temperature of the vapor (or air-vapor mixture) and the dew point is called the depression of the dew point. The amount of moisture in a space, expressed as a percentage of what the same space would contain at saturation, is the relative humidity. If relative humidity is subtracted from 100 per cent, the numerical result is called the saturation deficit.

Now let the following notation be adopted: $\mathbf{T}$ = dry-bulb reading, °F; $\mathbf{W}$ = wet-bulb reading, °F; $\mathbf{D} = \mathbf{T} - \mathbf{W}$; $\mathbf{p}$ = depression of the dew point, °F; $\mathbf{q}$ = saturation deficit, as a percentage.

By a systematic trial and error approach, the following formulas have been found, applicable when the barometric pressure is near the normal:

$$\mathbf{p} = \frac{100\,\mathbf{D}}{\mathbf{W}}, \qquad \mathbf{q} = \frac{344\,\mathbf{D}}{\mathbf{T} + .01\mathbf{T}\,\mathbf{D}}.$$

For example, if the dry and wet bulb respectively read 67.0° and 59.0°, the depression of the wet bulb would be 8.0°; and by the first formula the depression of the dew point would be $100 \times 8 \div 59 = 13.5°$. It follows that the dew point would be $67.0 - 13.5 = 53.5$°F. Similarly, by the second formula the saturation deficit would be $344 \times 8 \div (67 + .01 \times 67 \times 8) = 38\%$; hence the relative humidity would be 62 per cent.

When rounded off to the nearest degree, the error in the dew point due to the use of the formula in place of tables will not exceed one degree for wet-bulb depressions up to the following values:

Dry-Bulb Reading	Wet-Bulb Depression
100°F	9°F
80	18
60	15
40	10
30	3

This table shows that the formula is satisfactory within limits which are sufficient for most purposes. The error increases rapidly outside the limits tabulated. The formula for saturation deficit will give results within one per cent for all wet-bulb depressions likely to be encountered, for the dry bulb between 30° and 100°. The formulas may be adapted for use at a considerable elevation, or at abnormal pressures, if the expression on the right of each of the two formulas is multiplied by the fraction of normal barometric pressure which prevails: $\mathbf{B}/\mathbf{Bo}$, where $\mathbf{Bo}$ is 30 inches, 760 millimeters, depending on the units used, and $\mathbf{B}$ is the barometric pressure at the time of observation.

One use of the dew-point depression is the

*See also "How to Construct a Psychrometer and Fan," **Weatherwise,** Vol. 2, No. 1, February, 1949, page 21. —ED.

estimation of the height of the base of cumulus clouds, or of stratocumulus clouds on a windy day. An approximate rule is that the cloud base, in feet, will be 225p. The constant stated may vary in the opinion of different writers; for example, the factor 300 has been found to work better when the ventilation of the wet bulb depends on natural air movement alone.

Another use of the dew point is the forecasting of the minimum temperature during the night. When no change of air mass is expected, the next nocturnal minimum temperature will usually be close to the dew point observed during earlier hours. For a particular location, an improvement can be effected by constructing an equation on a statistical basis; the nocturnal minimum may be expressed as a function of, say, the early evening temperature, the dew point, and the wind speed, thus taking additional factors into account.

The formula for saturation deficit may be used to calibrate a hair hygrometer. Such an instrument will often have scattered errors of about five per cent even when set as well as possible. It is often suspected of having a large error, so check the reading occasionally.

Relative humidity is important in any situation connected with the drying of organic material. One special application is in the estimation of fire hazard in forests. The hazard depends on the dryness of the "duff," the bed of old coniferous needles, leaves, and twigs on the ground. Its dryness depends on recent weather conditions, among which the relative humidity over the past few days is an important element. Another large field of application is the control of relative humidity in some types of factories; textile, confectionery, and printing are examples.

Tables or nomograms should be used for finding dew points or relative humidity when they are available, but with the above easily remembered formulas, values will still be obtainable when tables are not at hand. When tables can't be found, you need not shed a tear, but be sure the wet bulb is really wet!

FOG IN THE LABORATORY

A fog-making machine is now under construction at the University of California that can simulate any condition of saturated air. Under the guidance of Professor Dan M. Finch, a U. S. Navy research project is gathering information on the size of fog particles, density of fogs, water content, temperature, dust content, and composition of dust. Professor Finch's fog maker is a double-walled tank, with windows through which the interior can be photographed and observed. Cold or warm moist air is introduced from a connecting vapor tank. In the fog tank the saturated air can be cooled or heated by circulation of warm or cold water in the jacket. It is hoped that from an exact knowledge of how fog forms much better means of fog dispersal may be worked out.

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AVIATION METEOROLOGY OF SOUTH AMERICA

AVIATION METEOROLOGY OF THE AZORES

Air Ministry Meteorological Reports Nos. 1 and 2. His Majesty's Stationery Office, London. No. 1, 5s; No. 2, 3s 6d.

IT IS HOPED that the Air Ministry Reports Nos. 1 and 2 of Volume 1 are the beginning of a series of papers covering the major air routes of the world.

Aviation Meteorology of South America and **Aviation Meteorology of the Azores** are not detailed studies, but rather comprehensive summaries of the weather in these two areas, and, as such, both have definite value. The volumes are well written and of interest to the general reader. These books would be of value to the meteorologist, pilot, or flight dispatcher anticipating service in the Azores or South America. They would also be of importance to climatologists or meteorologists wanting general information about these important and relatively little known areas.

The 50 pages of the pamphlet on South American aviation meteorology cover a great amount of information. A description of the topography, ocean currents, general circulation, and other pertinent data is followed by summaries of the climates of the various topographic areas of South America. The air masses are studied in some detail, as is seasonal weather over each main air route. A very good selection of synoptic maps illustrates weather types commonly encountered. The maps show the circulation and movement of pressure systems in the Southern Hemisphere so well that the reader begins to feel familiar with winds blowing clockwise around lows, and cold fronts moving north from their source regions. The appendix contains 14 pages of general climatological summaries.

This report is fairly general, but necessarily so as its scope is great, involving as it does a large continent extending from polar latitudes to the tropics.

In Report No. 2, a brief but thorough description of the geographical situation, vegetation, and climate of the Azores is followed by a survey of the dominant contributing factors to the rather interesting climate of the islands. These include important air masses and modifications, general topographic influences, and exposures of the various airfields to prevailing winds which account for the differing weather at each of the three airfields. The exposure of each of the eight reporting stations is described and also shown by diagrams. Good pictures of the airfields are included as well as plates showing topography and exposure of the Portuguese observatories. A brief description with synoptic maps showing typical frontal weather types is followed by a similar study of air mass weather types with summaries of cloud bases and visibilities at each of the airfields under typical conditions.

In Part Two, climatology of the islands is studied in some detail, including precipitation, visibility, clouds, winds, pressure, temperatures, upper air, sea and swell. The appendix contains general climatological summaries. This is the most comprehensive and complete study of the weather of the Azores that the reviewer has seen.

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NEW BOOKS RECEIVED

THE ATMOSPHERES OF THE EARTH AND PLANETS. *Various authors; edited by G. P. Kuiper.* University of Chicago Press, Chicago, 1949. 366 pages. 16 plates. $7.50.

Papers from the symposium on planetary atmospheres held at Yerkes Observatory, University of Chicago, in 1947, commemorating the 50th anniversary of the observatory. Meteorologists, geophysicists, and astronomers discuss observational and theoretical problems concerning the earth's atmosphere and those of the other planets in the solar system.

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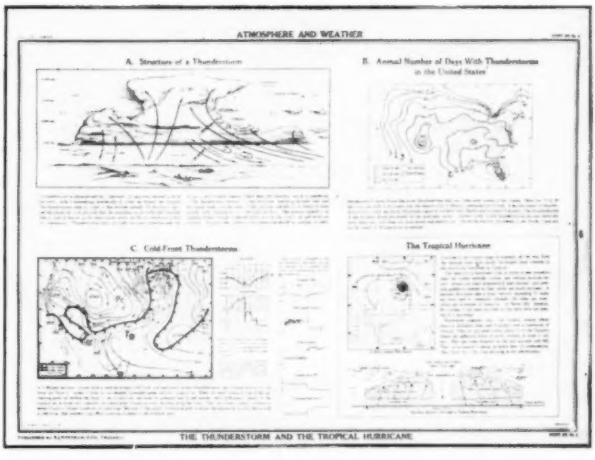
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